The Role of Executive Functions in ADHD Symptoms in University Students

Annemarij de Jong

S3940942

PSB3E-BT15 Bachelor Thesis

March 2023

Department of Psychology

Supervisor: dr. Norbert Börger

Second evaluator: dr. Pieter de Vries

A thesis is an aptitude test for students. The approval of the thesis is proof that the student has sufficient research and reporting skills to graduate but does not guarantee the quality of the research and the results of the research as such, and the thesis is therefore not necessarily suitable to be used as an academic source to refer to. If you would like to know more about the research discussed in this thesis and any publications based on it, to which you could refer, please contact the supervisor mentioned.

Abstract

Since ADHD in adults is underdiagnosed, additional research in this area is needed. Insight into Executive Functions (EFs) in adults with ADHD could potentially aid diagnosis. This paper investigated the relationship between ADHD symptoms and EFs in university students. The study was conducted online, and 229 participants took part in completing two questionnaires. The Conners' Adult ADHD Rating Scales (CAARS) and the Executive Function Index (EFI) were used to measure ADHD symptoms and EFs. The findings suggested that EFs were related to ADHD symptoms, but not all EFs were related as strongly as anticipated. First, a moderate, negative relationship was found between the EFI and ADHD symptoms which indicates that a lower level of executive functioning was related to more ADHD symptoms. Second, problems in Organization, Impulse Control, and Strategic Planning were associated with more ADHD symptoms. Problems in Motivation were unrelated to ADHD symptoms, as was the case for Empathy. Third, a backward elimination regression analysis gave Organization and Impulse Control as best predictors of ADHD symptoms. Executive dysfunction was more related to the DSM-IV ADHD rating scale of the CAARS than the CAARS ADHD Index. The current study contributes to the understanding of EFs and ADHD symptoms in students and provides more comparative data regarding adult ADHD and EFs for future research.

Keywords: ADHD symptoms, executive functions, motivation, inhibition, students

The Role of Executive Functions in ADHD Symptoms in University Students

Attention Deficit Hyperactivity Disorder or ADHD, defined by difficulties in attention-holding, impulse control, and hyperactivity is a neurodevelopmental disorder according to the DSM-5 (American Psychiatric Association [APA], 2013). To aid diagnosis, particularly in the adult population, there is still ground to be uncovered. The current study aims to analyse the relationship between Executive Functions (EFs) and students with ADHD and the particular role of inhibition and motivation in this relationship. The DSM-5 uses five criteria to diagnose adults. First, they are required to meet five or more symptoms for inattention and/or hyperactivity, and/or impulsivity. The DSM-5 distinguishes between three types based on the symptoms: predominantly inattentive, predominantly hyperactive-impulsive, and combined. Second, it needs to be shown that ADHD symptoms emerged at a young age (before the age of twelve). The third criterium is the occurrence of the aforementioned symptoms in at least two different contexts, such as at work and in one's private life. The fourth criterium is that these symptoms have a demonstrable detrimental impact on social, academic or, professional performance. The fifth requirement is the presence of strong evidence that the occurrence of symptoms is best explained by ADHD and not by another mental condition.

ADHD according to the DSM-5 is a categorical disorder, which means people will only be diagnosed with it if they have enough symptoms. However, research nowadays suggests that ADHD can be considered a dimensional disorder (Salum et al., 2014). It exists along a spectrum, fewer symptoms are linked to impairment as well (Vogel et al., 2018). This dimensionality means that the severity of symptoms should be taken into account for a full picture of the pathology (Heidbreder, 2015). An example of this is that in adult ADHD, symptoms are similar to those of childhood and adolescent ADHD, but the severity of symptoms, particularly hyperactivity, changes over time (Adler & Chua 2002). Hyperactivity, for example, can manifest in children as an inability to sit still or keep quiet, while hyperactivity in adults might express as feeling restless all the time.

Prevalence and underdiagnosis in adults

Based on results from the National Comorbidity Survey Replication of adult ADHD in the United States, about 4.4% of adults are estimated to have ADHD (Kessler et al., 2006). Although this study was conducted in the United States, the frequency of ADHD is similar in many other nations (Faraone et al., 2003). Many adults however still go undiagnosed and untreated for ADHD (Ginsberg et al., 2014; Kooij et al., 2019). Medical records report lower prevalence rates of ADHD in adults than self-report estimates in the population (Kessler et al., 2006, Prasad et al., 2018). This means that there are fewer adults with ADHD seen in the clinic than would be expected. The reasons why ADHD is underdiagnosed are still ambivalent. Asherson et al. (2012) suggest this is partially due to the social and cultural perception of ADHD that shape the understanding of how it typically manifests. Even though the DSM-5 has included symptoms for adults, the diagnosis itself is still mainly based on children (APA, 2013). Adults with ADHD often adapt their lives and employ coping strategies to compensate for their deficits, which makes adult ADHD more likely to go undetected (Asherson et al., 2012). This is in contrast with children with ADHD who have less opportunities and capabilities to adjust their situation. In other words, ADHD symptoms in adults might be harder to diagnose because they are more discreet and variable (Kessler et al., 2006). Finally, adults with ADHD often have comorbid psychiatric conditions (Anker, et al., 2018), or symptoms resemble symptoms of other disorders (Asherson et al., 2016). The overlap makes it harder to diagnose ADHD.

Consequences of underdiagnosis of ADHD in adults

People with ADHD have problems with attention-holding, impulse control, and hyperactivity during the course of their lives (Rovira et al., 2019), even into old age (Lensing et al., 2015; Thorell et al., 2019). ADHD in adults that is left unnoticed and or not properly treated is related to poorer health outcomes in the long run (Barbaresi et al., 2013). Some of the health complications associated with ADHD might be prevented by timely intervention. One example of an effect on physical health is that people with ADHD have a higher risk of developing early-onset and persistent smoking habits (Mitchell et al., 2018). The updated European Consensus Statement on Diagnosis and Treatment of Adult ADHD (Kooij et al., 2019) provides more information about the disadvantageous effects on physical well-being. Besides negative physical health outcomes associated with ADHD, persistent ADHD symptoms in adulthood can result in social and psychological impairment. Relationship issues, money issues, job stability, and poor performance at work are among the things that ADHD exacerbates (Kooij et al., 2019). Given the effectiveness of treatment (Arnold et al., 2015), early identification can lower the overall risk for adverse long-term consequences.

ADHD and executive functions

In summary, ADHD in adults is underdiagnosed and is linked to a number of negative effects on physical, social, and mental well-being. To aid diagnosis it is relevant to know how ADHD presents in adults. This paper will investigate the role of Executive Functions (EFs) in explaining ADHD symptoms. In the following paragraphs, further clarification is provided about what EFs entail, how it is important in ADHD, and what it could add to our understanding of adult ADHD.

Executive Functions

EFs are at the top of the entire mental system, they control and modulate all cognition. EFs are in charge of the brain's general capacity of interpreting the outside world (Freeman., 2001). In the literature, there is some variation in the exact definition as well as the number of EFs. One definition of EFs is ‘ those abilities required for deliberate, goal-directed behaviour’ (Anderson., 2001). An indication of five main EFs is provided by Spinella (2005): empathy, strategic planning, organization, impulse control, and motivation. Motivation encompasses activity level, interest, and curiosity. Organization is about planning and multitasking. Impulse control encompasses risk-taking behaviours. Poor impulse control can result in substance abuse or financial irresponsibility for example. Empathy is the individual's concern for the well-being of others, willingness to cooperate, and tendency to behave in a prosocial manner. Lastly, strategic planning can be thought of as envisioning future outcomes. This categorization is useful because the domains are neither too general nor too specific.

EFs depend on neurological or cognitive functions (Harvard, 2020). An overview by Diamond (2013) states that, in terms of executive functioning, there is general agreement about three core cognitive functions: Inhibition, Working Memory, and Cognitive Flexibility. Inhibition is of relevance to our research. Inhibition here is defined as being able to regulate one's attention, behaviour, thoughts, and/or emotions by ignoring in- or external incentives, to do what is more relevant or appropriate. The ability to retain and process information is known as working memory and cognitive flexibility is the ability to change tasks when necessary. These functions are highly intertwined, and good cooperation between them is necessary for the effective application of EFs (Harvard, 2020). Understanding how EFs contribute to ADHD symptoms and impairment could aid diagnosis of adult ADHD. EFs could differentiate ADHD from disorders with overlapping symptoms (Barkley, 2010).

Relationship between EF and ADHD

When considering the five EFs given by Spinella and the three core cognitive functions given by Diamond, some of the central deficiencies found in ADHD immediately come to mind. Inhibition, impulse control, and motivation overlap some ADHD symptoms by definition alone. Indeed, there is a large body of research showcasing a relationship between ADHD and EFs (Alaghband-rad et al 2020, Barkley and Biederman 1997; Kempton et al., 1999; Matte et al., 2012; Pennington and Ozonoff 1996; Seidman et al 1998; Sinha et al., 2008; Tamm et al., 2013; Willcutt et al., 2005; Weyandt et al., 2017). The frontal lobe and its subcortical connections, which entail EF, are commonly incorporated in neuropsychiatric efforts to interpret abnormalities found in ADHD (Luria, 1973; Becker et al., 1987). Evidence from neuroimaging techniques and behavioural research supports the connection between ADHD and EFs (Mattes, 1980, Riaz et al., 2020). Due to the neuro-physiological similarities, particularly in terms of brain location, executive functioning has been a key component of theories concerning the processes underlying ADHD.

Adult ADHD and EFs

The relationship between adult ADHD and EFs has gotten less attention than that between child ADHD and EFs (Loo et al., 2007). Research however has suggested that problems with EFs are present in all age categories of people with ADHD (Barkley and Biederman 1997; Pennington and Ozonoff 1996; Seidman et al 1998). The type of problems with EFs does change with age, as adults with ADHD face different, more complicated, and demanding cognitive challenges compared to children (Faraone et al., 2001). One group of adults with ADHD, namely students, has very specific challenges in terms of executive functioning. Students need to plan ahead, keep focused for extended periods of time, and ignore distractions to study efficiently, in other words, to succeed in academia they need to make proper use of EFs. Because of the nature of studying, it should come as no surprise that EFs deficiencies can harm academic achievement (Clark et al., 2002). All the while, EF deficiencies do occur often in students with ADHD (Biederman et al., 2004). According to Bueno et al. (2014), investigating precisely which EFs affect adult ADHD is necessary. They note that not all EFs are equally important in explaining adult ADHD. One study by Dvorsky and Langberg (2014) found motivation and organization as EFs that are most related to ADHD impairment in students. The authors note however that their study is limited in size and more research is needed. EFs in students with ADHD has not been explored much in research (Weyandt et al., 2013). The current study is aimed at the student population because of this gap. In addition, students form a relatively homogenous group with a comparable level of intelligence, which might facilitate interpreting results originating from differences in EFs rather than fluctuations in mental ability.

Models of ADHD

Merely focusing on general executive dysfunction does not suffice for a full understanding of ADHD, it offers an explanation that is perhaps too general and incomplete (Tsal et al., 2005). There are different models of how EFs are impaired in ADHD. Two theoretical perspectives will be considered in the present study. Barkley’s theory of self-control and ADHD (Barkley, 1997) and Meere and colleagues work on the State Regulation Model (Van der Meere et al., 2010). In his effort to find an encompassing theory of ADHD, Barkley suggests that deficits in overall executive functioning are explained by impaired inhibitory control. Inhibition is an executive function in and of itself, but, due to its large impact, it affects many activities, including those that seemingly only burden other EFs (Barkley, 1997). The idea that the association between ADHD and executive changes is solely due to impaired inhibition has been supported by other research as well (Bekker et al., 2005; Boonstra et al., 2010). In contrast, the psychophysiological state regulation model considers impaired inhibition alone an inadequate explanation. Van der Meere et al. (2010) consider motivation as the underlying factor in deficits seen in ADHD. The state regulation model posits that motivation is an important element in the initiation, continuation, and controlling of activity. In other words, here overall activation is the process by which EFs are either enhanced or impaired. This would imply a top-down view of why executive dysfunction occurs in ADHD, however, the authors, note that bottom-up and top-down processes can be influential simultaneously.

Current research

The aim of the current research is to gain more insight into the diagnosis of ADHD in adults. To do so, the association between EFs and ADHD will be examined university students. Conners' Adult ADHD Rating Scale (CAARS) will be used to measure ADHD symptoms and the Executive Function Index (EFI, Spinella, 2005) will be used to measure EFs. The present study will seek to answer three questions, one concerning the general relationship between EFs and ADHD and two about individual EFs and ADHD.

The first question is: *is there is a relationship between EFs and ADHD symptoms in university students?* There is evidence that EFs, in general, are linked to ADHD in adults, people with poor executive function skills are more likely to have ADHD-related problems (Alaghband-rad et al 2020, Barkley and Biederman 1997; Kempton et al., 1999; Matte et al., 2012; Pennington and Ozonoff 1996; Seidman et al 1998; Sinha et al., 2008; Tamm et al., 2013; Willcutt et al., 2005; Weyandt et al., 2017). Therefore, it is expected that people who score lower on the EFI, will show more ADHD symptoms, first measured with the CAARS ADHD Index and second with the DSM-IV ADHD Total symptoms.

The second question is: *are specific EFs related to ADHD symptoms in university students?* In the literature, there is yet no clear answer to the question of which EFs are most impaired in ADHD and how strong the relationships between individual EFs and ADHD symptoms are (Bueno et al., 2014; Dvorsky & Langberg, 2014; Willcutt et al., 2005).

Executive dysfunction in ADHD is thought of as a problem with self-regulation (Barkley, 1997; Modi et al., 2018; Van der Meere et al. 2010). This points to inhibition and motivation as EFs that are most central to problems in ADHD. Indeed, there are several studies where tasks that evaluate inhibition are found to be involved in impairments seen in ADHD. (Bekker et al., 2005; Boonstra et al., 2005; Boonstra et al., 2010; Miller et al., 2012). Some work even suggests that inhibitory control is the primary problem in ADHD (Slobodin 2015). There is evidence as well supporting the role of motivational deficits as a factor in adult ADHD (Bioulac et al., 2016) and in students with ADHD impairment in motivation is also found (Sibley et al., 2019). The second question is divided into two parts. First, it is expected that Motivational Drive is related to ADHD symptoms and more so than Strategic Planning, Organization, and Empathy. Second, it is expected that Inhibitory control is related to ADHD symptoms and more so than Strategic Planning, Organization, and Empathy. It is expected that people with lower scores on Motivational Drive and Inhibitory Control, as measured by the EFI, will show more ADHD symptoms, measured by the CAARS ADHD Index and the DSM-IV ADHD total symptoms.

The third question is: *Which EFs best predict ADHD symptoms in university students?* This is an extension of the second research question. The present study will use two theoretical frameworks to predict ADHD symptoms: Barkley's theory of self-control (Barkley, 1997) and van der Meere et al.'s State Regulation Model (Van der Meere et al., 2010). Barkley proposes that inhibitory dysfunction is a predictor of ADHD symptoms and Van der Meere et al.'s model suggests that ADHD symptoms are a manifestation of a motivational problem. Therefore, it is expected that Impulse Control and Motivational drive explain most of the variation in ADHD symptoms. Two multiple regression analyses were conducted. In the first regression analysis, the CAARS ADHD Index was used as a measurement of ADHD symptoms. In the second regression analysis, the DSM-IV ADHD total symptoms was used as a measurement of ADHD symptoms. The Motivational Drive subscale of the EFI was used to measure motivation, whereas the Impulse Control subscale was used to assess inhibition. All subscales of the EFI were employed as independent factors and ADHD symptoms, as measured by the CAARS ADHD Index and the DSM-IV ADHD total symptoms, served as the dependent variable.

Method

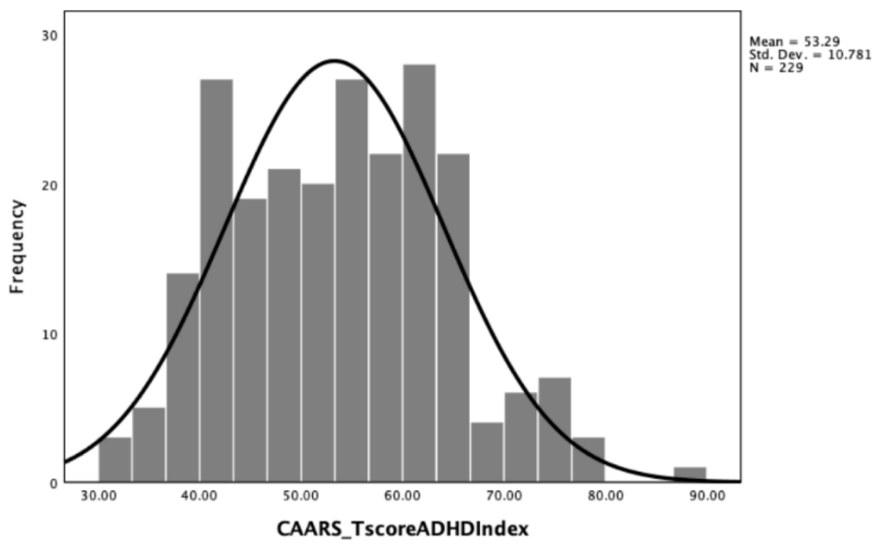
Participants

For the current study, all participants were obtained through SONA, which means that the sample consisted of students from the University of Groningen. By partaking in the study the participants could earn SONA points, which were required for their study. The sample consisted of non-clinical participants. People with a diagnosis of ADHD have not been specifically selected for, but people with a diagnosis have not been excluded either. A good comprehension level of the English language was a prerequisite to participate.

In total, 266 persons filled in questionnaires to measure ADHD symptoms and EFs. Of these, 27 participants did not fully complete the questionnaires and were thus removed from the dataset. In addition, participants younger than 18 and older than 29 had to be removed from the sample, based on this criterium nine participants were removed. One participant who had entered gender as 'other' was removed as well, their data could not be used because the CAARS does not have criteria for this group. This resulted in a final sample of 229 participants for the questionnaires, of which 46 were male and 183 were female. The mean age of the participants was 19.7 years (*SD* = 1.68, min = 18, max = 29). There were 57 participants who reported being diagnosed with a physical, mental, or neurological condition and 35 participants reported using medication. Figure 1 shows that the *T*-scores of the ADHD index of the CAARS are skewed to the right. This means that there are relatively more participants with low ADHD scores than there are participants with high ADHD scores on the CAARS.

Figure 1

Distribution of CAARS T-Scores



Materials

Conners' Adult ADHD Rating Scales

The Conners' Adult ADHD Rating Scales (CAARS, Conners et al., 1999) was used to measure ADHD symptoms. The CAARS has been developed for adults aged 18 to 50 years and older. The CAARS consists of 66 items and participants were asked to answer on a 4-point Likert scale from 0 (not at all) to 3 (very often). The CAARS relies on self-report, so participants had to indicate what the 'best' answer was for them. The long version of the CAARS was used in the present study, which takes approximately 30 minutes to complete.

The CAARS consists of nine subscales. The first four subscales, which were obtained through factor analysis, are inattention/memory problems, hyperactivity, impulsivity/emotional lability, and problems with self-concept. A high score on each subscale means that there are more problems in that scale. These four subscales appear to be suitable for investigating ADHD symptoms in adults. In addition, the CAARS contains three subscales that correspond based on the DSM-IV criteria for ADHD. These subscales are symptoms of inattention, hyperactive-impulsive symptoms, and total ADHD symptoms based on the DSM (DSM Total). The last two subscales are an ADHD index and an inconsistency index. The ADHD Index includes a set of items that give a general impression of ADHD and help distinguish adults with ADHD from adults without ADHD. The inconsistency index enables us to determine whether certain participants should be removed from the dataset.

T-scores will be calculated so that corrections can be made for age and gender. *T*-scores greater than 70 are clinically significant and indicate the presence of a clinical symptom in adults with no officially identified problems. In general, higher scores indicate more symptoms of ADHD. The *T*-scores were calculated for all scales so that the CAARS ADHD Index *T*-score and the CAARS DSM Total *T*-score could be calculated. The *T*-scores of the CAARS ADHD index and DSM-total score are used in further analysis.

The Cronbach's alpha for men ranges from 0.64 to 0.91 and for women from 0.49 to 0.91 (Macey, 2003). Since Cronbach's alpha is around 0.7, this indicates fairly reliable internal consistency. The test-retest reliability is between 0.88 and 0.91, which means good test-retest reliability. Sensitivity and specificity are high for the first four subscales. The construct validity of the CAARS is satisfactory.

Executive Function Index

The Executive Function Index (EFI; Spinella, 2005) is a questionnaire intended for the general population of adults and is used in this study to measure executive functions in everyday life in college students (Mohamed et al., 2021). Originally, this questionnaire was developed in a population of students, making it suitable for the current study (Janssen et al., 2009). The EFI questionnaire consists of 27 items measured on a 5-point Likert scale from 1 (not at all) to 5 (very much) (Spinella, 2005). In this questionnaire, various items are measured using five subscales namely Motivational Drive (e.g., behavioural drive, activity level, interest, and curiosity), Organization (e.g., multitasking, sequencing, and keeping things in mind), Impulse Control (e.g., risk-taking, substance abuse, or excessive spending), Empathy (e.g., an individual's concern for the well-being of others, tendency to behave prosocially, and level of cooperative attitude) and Strategic Planning (e.g., anticipating consequences, using strategies to save money). The subscales Motivation and Impulse Control consist of four items and the subscales Empathy and Organization both have six items, finally, the subscale Strategic Planning contains seven items. An example of an item on the Empathy subscale is: “I take other people's feelings into account when I do something”. Another example of an item on the Organization subscale is: “I have trouble when doing two things at once, multitasking”. The EFI can be used for both clinical and non-clinical purposes. Of the subscales Motivational Drive, Organization, Impulse Control, and Empathy, 13 items were scored inversely. These had to be reversed to ensure that a higher score reflects better executive functions (Spinella, 2005). The total score of the EFI is calculated as the sum of all items. For all subscales, a higher score indicates better executive functioning. The sum scores of the five subscales and the final overall score of the EFI were utilized in the analyses, after adjusting the reversed scored scales.

The EFI was developed to bridge the gap between subjective and objective methods of measuring executive function, resulting in a test that is particularly useful for measuring this variable in large groups. The final subscales are consistent not only with previous executive function questionnaires but also with twelve neuropsychological and neurophysiological tests of executive function. Although the EFI is a subjective test based on self-report, this test correlates with, for instance, FMRI scans (Spinella, 2005). This is important in the current study, as both ecological validity and construct validity can be ensured as well as possible. In addition to the correlation between the EFI and FMRI scans, there is a strong correlation between the EFI and other self-report-based measures of executive function. The internal consistency for the EFI is reasonable, with Cronbach's alpha ranging from 0.69 to 0.82.

Procedure

The survey was conducted online and participants could complete the questionnaire online by phone or computer. Participants were collected via SONA. In Qualtrics (2022), the participants were informed about the purpose of the surveys, contact details for any questions, the duration of the questionnaire, and about the anonymity of their data. The participants were also informed that quitting was possible at any time without negative consequences. After the participants gave their consent, the questionnaire was started and the participants could fill in their age, gender, and native language. In addition, information was requested about possible physical or mental disorders and the use of medication for the CAARS questionnaire. Once this was completed, participants were able to complete the CAARS questionnaire, which took approximately 30 minutes. After completion of the CAARS, participants were required to consent to their scores being used for the EFI. For the EFI, the participants were also asked to sign consent. After both CAARS and EFI, participants were asked if they had any comments about the study. The CAARS and EFI both lasted about 20 minutes. Participants did not have to complete both surveys, as they received SONA credits for the surveys individually.

Data analysis

All *T*-scores of the subscales of the CAARS, the total score of the EFI, and the sum scores of the five subscales of the EFI were used to analyse the data. Descriptive statistics of the data (means and standard deviations) are presented in Table B in Appendix B. The data were analysed with the SPSS Statistics program (Version 26). It was tested whether the data was normally distributed using the Shapiro-Wilk test. A significant result indicates that the data is not normally distributed. All tests of the scales used had a significant outcome ($p \leq .006$), which means that the data was not normally distributed, see Figure 1 above and Table A in Appendix A. Because of non-normally distributed data, the nonparametric Spearman correlations were used in the current study to examine associations between ADHD symptoms and executive functioning.

For the first two research questions, the nonparametric Spearman rank correlation test was used to test the correlations. For all correlations, there were 229 data points. For the first question, correlations between total scores on the EFI, and CAARS subscales ‘ CAARS ADHD Index’ and ‘CAARS DSM-IV ADHD Total Symptoms’ were used. For the second question, correlations between individual EFI subscales and CAARS subscales ‘ CAARS ADHD Index’ and ‘CAARS DSM-IV ADHD Total Symptoms’ were used. Because a total of ten comparisons were made, the alpha level was adjusted to .005 using the Bonferroni correction.

To answer the third research question, a multiple regression analysis was conducted using the backward elimination method. To analyse which variable or variables would best explain variation in ADHD symptoms, the analysis was done for two CAARS subscales; 'CAARS ADHD Index' and 'DSM-IV ADHD Total Symptoms'. Here 'CAARS ADHD Index' and 'DSM-IV ADHD Total Symptoms' were put as dependent variables, and the EFI subscales were considered predictors. To check for any pattern in the residuals, scatterplots were used to control for even variance of the residuals. The variance of the residual seemed constant, as can be seen in Appendix F, Figure F1 and Figure F2.

Results

Relationship between the EFI and ADHD symptoms

It was expected that the EFI would be negatively correlated to ADHD symptoms. First, it was found that the correlation between the EFI and the CAARS ADHD Index was significant. Second, it was found that the correlation between the EFI and the DSM-IV ADHD Total symptoms was significant. A moderate, negative correlation was found between the ADHD index of the CAARS and the total scores on the EFI (rs (227) = .40, $p < .001$). The correlation scatterplot (Figure 2a, p. 16) shows this negative relationship between CAARS ADHD Index and total scores on the EFI (R^2 = .18, $F(1, 228) = 48.282$, $p < .001$). There was also a moderate, negative relation between DSM-IV ADHD Total Symptoms and the EFI ($rs(229) = -.45$, $p < .001$). The correlation scatterplot in Figure 2b (p. 16) shows the negative relationship between the total EFI scores and DSM-IV ADHD Total Symptoms (R^2 = .22, $F(1, 228) = 65.032$, $p < .001$). These figures illustrate that people who score higher on executive functioning as measured by the EFI show less ADHD symptoms, as measured by the CAARS ADHD Index and the DSM-IV ADHD Index.

Figure 2a

Relationship CAARS ADHD Index and EFI Total

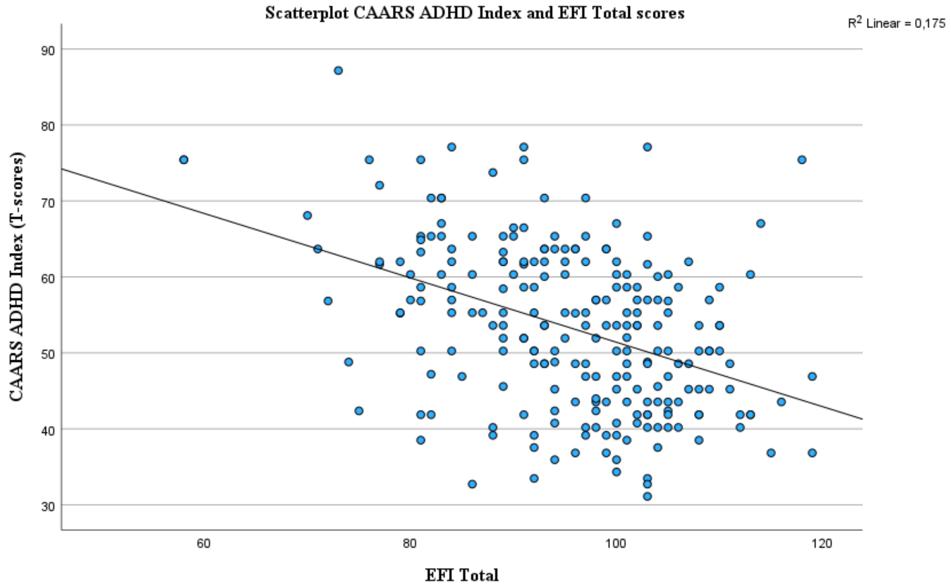
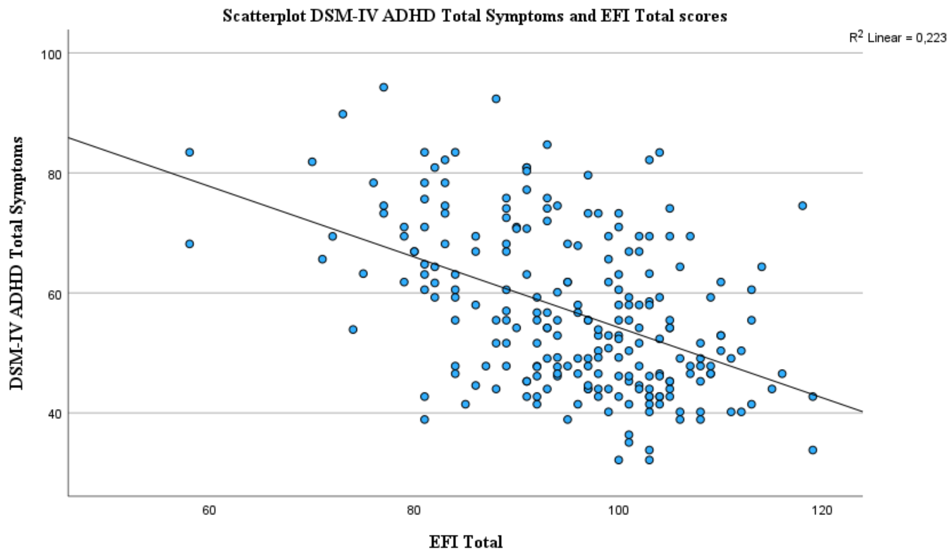


Figure 2b

Relationship DSM-IV ADHD Total Symptoms and EFI Total



Relationship between specific EFs and ADHD symptoms

It was expected that Motivational Drive would be related to ADHD symptoms, and more so than Strategic Planning, Organization, and Empathy. Results were not in line with this expectation. No correlation was found between Motivational Drive and the CAARS

ADHD Index (rs (227) = -.07, p .31). There was also no association found between Motivational Drive and DSM-IV ADHD Total Symptoms (rs (227) = .05, p .31). Thus, there seems to be no association between Motivational Drive and ADHD symptoms in this sample.

It was also expected that Inhibitory Control would be related to ADHD symptoms, and more so than Strategic Planning, Organization, and Empathy. The results were in line with the first, but not the second part of this expectation. A weak, negative relationship was found between Impulse Control and the CAARS ADHD Index ($rs(227) = -.30$, $p < .001$) A moderate, negative relationship existed between Impulse Control and DSM-IV ADHD Total Symptoms ($rs(227) = -.41$, $p < .001$), meaning that lower scores on impulse control were related to more ADHD symptoms. Organization was found to be related to both the CAARS ADHD Index ($rs(227) = -.51$, $p < .001$) and DSM-IV ADHD Total Symptoms ($rs(227) = -.54$, $p < .001$). Strategic Planning was related less strongly to the CAARS ADHD Index ($rs(227) = -.21$, p .001) and DSM-IV ADHD Total Symptoms ($rs(227) = -.27$, $p < .001$) than Impulse Control. Correlations for all EFI subscales can be found in Table C in appendix C.

Regression of EFs on ADHD symptoms

Two stepwise regression analyses were performed. The first analysis was of all variables of the EFI on the CAARS ADHD Index and the second analysis was of all variables of the EFI on DSM-IV ADHD Total Symptoms. For both regression analyses the same procedure was used. The predictor variables were Empathy, Strategic Planning, Organization, Impulse Control, and Motivational Drive. A linear regression model was used with the backward stepwise selection method. At each step, variables were excluded according to p-value ($p > .1$). The final model was determined with a p-value threshold ($p < .05$).

The variable exclusion process and the final predictor variables were the same for the first as well as the second analysis. Table D2 in appendix D shows the model summary of the regression analysis of all variables of the EFI on the CAARS ADHD Index. The first model, which contained all five candidate variables, accounted for approximately 27% of the variance of the total scores on the CAARS ADHD Index ($R^2_{adj} = .267$, R^2 change = .000 step 1 in table D2). In the second model, Strategic Planning was removed, this did not impact the explained variance ($R^2_{adj} = .271$, R^2 change = .000; step 2 in table D2). In the third model, Empathy was removed, this also did not impact the explained variance ($R^2_{adj} = .274$, R^2 change = .000; step 3 in table D2). In the fourth model, Motivational Drive was removed, the explained variance decreased slightly but this was not significant ($R^2_{adj} = .273$, R^2 change = -.004; step 4 in table D2).

Table E2 in appendix E shows the model summary of the regression analysis of all variables of the EFI on the CAARS DSM-IV ADHD Total Symptoms. The first model, accounted for approximately 35% of the variance of the total scores on the CAARS ADHD Index (R^2_{adj} = .349, step 1 in table E2). In the second model, Strategic Planning was removed which did not significantly impact the explained variance (R^2_{adj} = .351, R^2 change = -.001; step 2 in table E2). In the third model, Empathy was removed, this also did not significantly impact the explained variance (R^2_{adj} = .349, R^2 change = -.005; step 3 in table E2). In the fourth model, Motivational Drive was removed, the explained variance decreased only slightly but this was not significant (R^2_{adj} = .348, R^2 change = -.004 step 4 in table E2).

In sum, starting with 5 variables, backward stepwise linear regression eliminated three variables from the model. In model 4, Organization and Impulse Control were left, both being negatively associated with the ADHD Index of the CAARS. These variables were also left in the final model of the regression analysis of all variables of the EFI on DSM-IV ADHD Total Symptoms. Statistical data of the regression analysis of all variables of the EFI on the CAARS ADHD Index can be found in Appendix D in Table D1. Statistical data of the regression analysis of all variables of the EFI on the DSM-IV ADHD Total Symptoms can be found in Appendix E in Table E1. Thus, results were not in line with the expectation that Motivational Drive would predict ADHD symptoms. There was support for Impulse Control as a predictor of ADHD symptoms. Organization explained most variation in ADHD symptoms, more so than Impulse Control.

Discussion

The present study investigated the relationship between EFs and ADHD symptoms among university students. The first question was whether ADHD and general executive functioning were related and results indicated that the EFI was related to ADHD symptoms. The second question aimed to see whether differences existed in which EFs were associated to ADHD symptoms. Results confirmed that this was the case, however not every EF was as strongly related as anticipated. A relationship was found between Inhibitory Control and ADHD symptoms, but Motivational Drive was unrelated to ADHD symptoms. The third question was which EF or EFs would predict ADHD symptoms. Linear regression analysis suggested that Organization and Inhibitory Control best predicted ADHD symptoms.

For the first question, the results were in line with the expectations. Lower scores on the EFI were linked to more ADHD symptoms. The current study provides further support for the idea that EFs are involved in ADHD. It is interesting to see that executive dysfunction is tied to ADHD symptoms in this population of university students. This suggests that EF problems proceed to be relevant also for people with ADHD in university, an environment where people are expected to have highly developed EFs. The results are concordant with other research. The strength of the relationship was moderate, indeed EFs as a whole do not relate one on one with ADHD symptoms.

The second question was whether specific EFs were related to ADHD symptoms. This question was divided into two parts. For the first part of the second question, it was expected that Motivational Drive would be related to ADHD and more so than the other EFs, with the exception of Inhibitory Control. For the second part of the second question, it was expected that Inhibitory Control would be related to ADHD and more so than the other EFs, with the exception of Motivational Drive. For the first part of the second question, the results were not in line with the expectations. It was found that differences existed between separate EFs and ADHD symptoms, but not in the way that was predicted. Organization, Impulse Control and Strategic Planning were related to ADHD symptoms while other EFs, namely Motivational Drive and Empathy were not related. This means that problems in Organization, Impulse Control and Strategic Planning were linked to more ADHD symptoms.

Lower scores on Motivational Drive were not related to ADHD symptoms. The finding that Motivational Drive was unrelated to ADHD symptoms was unexpected and contrasted with the findings of Sibley et al. (2019), they did find validation for the role of motivation in explaining ADHD impairment in students. However, Sibley et al. note that for intrinsic motivation, differences between individuals with and without ADHD tend to decrease over time and this is related to the complexity level of academic work. The sample of Sibley et al. consisted of high school students, in the present study only university students took part. Therefore, one explanation for the lack of correlation between Motivational Drive and ADHD symptoms is that university students generally do not struggle with motivation or have developed coping mechanisms for dealing with motivational problems during the course of their learning. The latter might be influential. The current study measured motivation via self-report, while other studies that did find support for the role of motivation measured it on the psychophysiological level (Bioulac et al., 2016; Sibley et al. 2019). Van der Meere et al.'s model, which served as a theoretical foundation, is based on a psychophysiological notion of motivation as well. Therefore, it could still be the case that on a more basic level, problems in motivation are related to ADHD symptoms in adults. On a behavioural level however, which is reported in questionnaires, it does not show up because of learned coping mechanisms, maybe particularly present in an academic population.

The results were in line with expectations for the second part of the second research question. A negative relationship was found between Impulse Control and ADHD symptoms, this means that students who had poorer Impulse Control also showed more ADHD symptoms. This finding is in line with the work of Barkley (1997) and other studies examining the role of inhibition in ADHD impairment (Bekker et al., 2005; Boonstra et al., 2005; Boonstra et al., 2010; Miller et al., 2012; Slobodin, 2015). Noteworthy is that Organization was related more strongly to ADHD symptoms than IC. Although a surprising result in the current study, this finding does align with the aforementioned study done by Dvorsky et al. (2014). They found that organizational skills were important in predicting ADHD-related impairment in college students.

For the third research question, results were not entirely in line with expectations. Impulse Control was a predictor of ADHD symptoms in university students but Motivational Drive was not. The findings support Barkley's theory, inhibition does appear to be a relevant factor in explaining ADHD impairment. The results in the current study do not provide support for the state-regulation model. As noted earlier, this may be explained by the fact that motivation was assessed in the present study using the EFI Motivational Drive scale, whereas Van der Meere et al. (2010) used experimental methods built upon a psychophysiological model. In the second research question Organization was related most strongly to ADHD followed by Impulse Control, the regression analysis showed the same pattern, giving Organization and Impulse Control as predictors of ADHD symptoms. It is worth noting that the analysis of the second research question showed that Strategic Planning was related to ADHD symptoms but this variable was not included in the final models.

One final interesting finding was that the difference in how the DSM-IV ADHD Total symptoms scale related to the EFI compared to the CAARS ADHD Index. The relationship between the total EFI scores and the DSM-IV ADHD Total symptoms scale was stronger than the relationship between the total EFI scores and CAARS ADHD Index. The same was found for subscales of the EFI, the same subscales had below threshold p-values in both DSM-IV ADHD Total symptoms and CAARS ADHD Index, but the correlations were higher for the DSM-IV ADHD Total symptoms. Lastly, this pattern was seen in the regression analyses as well. The DSM-IV ADHD Total symptoms is more based on children but the findings seem to suggest that the DSM-IV scale is sensitive enough to detect ADHD in university students as well. However, it is unknown whether the difference is meaningful or not. Either way, the results suggest that future research should be aware of a possible difference between the scales. If executive dysfunction turns out to be more related to the DSM-IV ADHD scales, it is of interest to see what causes that difference.

Limitations and future research recommendations

There were some limitations of generalizability concerning the sample. University students are a select group of people who might not be representative of the general adult population. Because of different social contexts, skill sets, career and lifestyle choices the results might not hold for other adult groups. Besides the student sample, the majority of the participants was female, and gender differences exist for scores on the EFI. Females, on average, score higher than males on measures of executive function (Spinella, 2005). One final important note on the sample is that there was an underrepresentation of people with high scores on ADHD symptoms, as can be seen in Figure 1 above.

One factor that might have influenced reliability of the results is that the study was conducted online, which gave little control over the conditions in which the questionnaires were taken. It could be the case that background noise or other environmental distractors influenced the results.

Notwithstanding the validity of the self-report measures that were used, the current study still relied on subjective evaluation of ADHD symptoms. Perhaps not all facets of ADHD symptoms were covered. Experimental measures might yield different results. However, the use of self-report measures provides comparative data for research in this area that uses physiological tests or experimental tasks.

These strengths and limitations provide a starting point for future research. The questionnaires could be administered to samples that are more representative of non-student populations. It would also be interesting to measure the different EFs on an experimental level next to the use of questionnaires, in the study of ADHD impairment. For example, the results regarding motivation are not in concordance with other research done in the area of ADHD and EFs in students (Dvorsky et al., 2014; Sibley et al., 2019). Sibley et al. used self-report and an experimental task, further analysis on a psychophysiological level might provide an answer as to why this difference exists. Future research could, for example, incorporate a go-no-go task to measure response inhibition and motivational level. Organizational skill on the other hand was not expected to be involved in ADHD symptoms but results showed otherwise, future research could investigate this EF in more detail. The difference between the DSM-IV ADHD total scales and the CAARS ADHD Index is also noteworthy, more research is needed to see how these scales relate to executive functioning. It could be that this effect is reserved only to the sample used in the current study.

Conclusion

ADHD is underdiagnosed in the adult population, more research is needed to establish how adult ADHD presents. The present study was an effort to aid diagnosis by focusing on the role of EFs, gaining insight into which EFs are involved might explain what adults with ADHD struggle with. The results suggested that problems with executive functioning are present also in university students with ADHD. The present study found support for the idea that ADHD symptoms may be driven, partially, by inhibitory dysfunction. Motivation was unrelated, although it is yet unclear if this was due to it being evaluated based on self-report. The findings of the present study give reason to further investigate Organization as an EF that could potentially be meaningful in explaining ADHD symptoms, as Organization came forward as the strongest predictor of ADHD symptoms. A surprising finding was that, in this student sample, EF scores were more related to the DSM-IV scale measuring core ADHD symptoms than the CAARS scale specifically developed for adults. It is unclear whether the differences are notable and future research could investigate whether EFs relate more to the DSM-IV scale in other adult demographics. Regardless of the ADHD symptom scale that was used, the results do further support the notion that executive dysfunction is part of ADHD impairment. Many intricacies of the association between EFs and ADHD are still unknown, more research in this area could aid both diagnosis and treatment.

References

Adler, L.A., & Chua, H.C. (2002). Management of ADHD in adults. *The Journal of clinical psychiatry, 63 Suppl 12*, 29-35

Alaghband-rad, J., Dashti, B., Tehranidoost, M., Zargarinejad, G., & FarhadBeigi, P. (2020). A preliminary investigation of deficits in executive functions of adults with attention deficit hyperactivity disorder. *Journal of Nervous & Mental Disease*, *209*(1), 35–39. https://doi.org/10.1097/nmd.0000000000001247

American Psychiatric Association, DSM-5 Task Force. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™* (5th ed.). American Psychiatric Publishing, Inc.. https://doi.org/10.1176/appi.books.9780890425596

Anderson, V. (2001). Assessing executive functions in children: biological, psychological, and developmental considerations. *Pediatric Rehabilitation, 4*, 119 - 136.

Anker, E., Bendiksen, B., & Heir, T. (2018). Comorbid psychiatric disorders in a clinical sample of adults with ADHD, and associations with education, work and social characteristics: A cross-sectional study. *BMJ Open*, *8*(3). https://doi.org/10.1136/bmjopen-2017-019700

Arnold, L. E., Hodgkins, P., Caci, H., Kahle, J., & Young, S. (2015). Effect of treatment modality on long-term outcomes in attention-deficit/hyperactivity disorder: A systematic review. *PLOS ONE*, *10*(2). https://doi.org/10.1371/journal.pone.0116407

Asherson, P., Akehurst, R., Kooij, J. J., Huss, M., Beusterien, K., Sasané, R., Gholizadeh, S., & Hodgkins, P. (2012). Under diagnosis of adult ADHD. *Journal of Attention Disorders*, *16*(5_suppl). https://doi.org/10.1177/1087054711435360

Asherson, P., Buitelaar, J., Faraone, S. V., & Rohde, L. A. (2016). Adult attention-deficit hyperactivity disorder: Key conceptual issues. *The Lancet Psychiatry*, *3*(6), 568–578. https://doi.org/10.1016/s2215-0366(16)30032-3

Barbaresi, W. J., Colligan, R. C., Weaver, A. L., Voigt, R. G., Killian, J. M., & Katusic, S. K. (2013). Mortality, ADHD, and psychosocial adversity in adults with childhood ADHD: A prospective study. *Pediatrics*, *131*(4), 637–644. https://doi.org/10.1542/peds.2012-2354

Barkley, R., & Biederman, J., (1997). Toward a broader definition of the age-of-onset criterion for attention-deficit hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(9), 1204–1210. https://doi.org/10.1097/00004583-199709000-00012

Barkley, R. A. (2010). Differential diagnosis of adults with ADHD. *The Journal of Clinical Psychiatry*, *71*(07). https://doi.org/10.4088/jcp.9066tx1c

Becker, M. G., Isaac, W., & Hynd, G. W. (1987). Neuropsychological development of nonverbal behaviors attributed to “frontal lobe” functioning. *Developmental Neuropsychology*, *3*(3-4), 275–298. https://doi.org/10.1080/87565648709540381

Bekker, E. M., Overtoom, C. C. E., Kooij, J. J. S., Buitelaar, J. K., Verbaten, M. N., & Kenemans, J. L. (2005). Disentangling deficits in adults with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry*, *62*(10), 1129. https://doi.org/10.1001/archpsyc.62.10.1129

Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E.Ferrero, F. 2004. Impact of executive function deficits and attention-deficit/hyperactivity disorder on academic outcomes in children. *Journal of Consulting and Clinical Psychology*, 72: 757–766.

Bioulac, S., Sagaspe, P., Micoulaud-Franchi, J.-A., Altena, E., Taillard, J., Schröder, C., Bouvard, M.-P., Fabrigoule, C., & Philip, P. (2016). Objective level of alertness and inhibitory control predict highway driving impairment in adults with ADHD. *Journal of Attention Disorders*, *24*(11), 1475–1486. https://doi.org/10.1177/1087054716633751

Boonstra A. M., Oosterlaan J., Sergeant J. A., Buitelaar J. K. (2005). Does methylphenidate improve inhibition and other cognitive abilities in adults with childhood-onset ADHD? *Journal of Clinical and Experimental Neuropsychology*, 27, 278-298. Crossref. PubMed

Boonstra, A. M., Kooij, J. J., Oosterlaan, J., Sergeant, J. A., & Buitelaar, J. K. (2010). To act or not to act, that’s the problem: Primarily inhibition difficulties in adult ADHD. *Neuropsychology*, *24*(2), 209–221. https://doi.org/10.1037/a0017670

Bueno, V. F., da Silva, M. A., Alves, T. M., Louzã, M. R., & Pompéia, S. (2014). Fractionating executive functions of adults with ADHD. *Journal of Attention Disorders*, *21*(11), 944–955. https://doi.org/10.1177/1087054714545537

Clark, C., Prior, M. and Kinsella, G. 2002. The relationship between executive function abilities, adaptive behaviour, and academic achievement in children with externalizing behaviour problems. *Journal of Child Psychology and Psychiatry, 43: 785–796.*

Conners, C. K., Erhardt, D., & Sparrow, M. A. (1999) Conners Adult ADHD Rating Scales (CAARS). New York: Multihealth Systems, Inc.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dvorsky, M. R., & Langberg, J. M. (2014). Predicting impairment in college students with ADHD: The role of executive functions. *Journal of Attention Disorders*, *23*(13), 1624–1636. https://doi.org/10.1177/1087054714548037

Faraone SV, Sergeant J, Gillberg C, Biederman J (2003): The worldwide prevalence of ADHD: Is it an American condition? World Psychiatry 2:104 –113

Faraone, S. V., Biederman, J., Spencer, T., Wilens, T., Seidman, L. J., Mick, E., & Doyle, A. E. (2001). Attention-deficit/hyperactivity disorder in adults: An overview. *Attention Deficit Hyperactivity Disorders*, 89–101. https://doi.org/10.4324/9781315054315-7

Freeman, W. J. (2001). *How brains make up their minds*. Columbia University Press.

Ginsberg, Y., Quintero, J., Anand, E., Casillas, M., & Upadhyaya, H. P. (2014). Underdiagnosis of attention-deficit/hyperactivity disorder in adult patients. *The Primary Care Companion For CNS Disorders*. https://doi.org/10.4088/pcc.13r01600

Harvard University (2020, March 24). *Executive Function & Self-regulation*. Center on the Developing Child at Harvard University. Retrieved December 24, 2022, from https://developingchild.harvard.edu/science/key-concepts/executive-function/

Heidbreder, R. (2015). ADHD symptomatology is best conceptualized as a spectrum: A dimensional versus unitary approach to diagnosis. *ADHD Attention Deficit and Hyperactivity Disorders*, *7*(4), 249–269. https://doi.org/10.1007/s12402-015-0171-4

Kempton, S., Vance, A., Maruff, P., Luk, E., Costin, J., & Pantelis, C. (1999). Executive function and attention deficit hyperactivity disorder: Stimulant medication and better executive function performance in children. *Psychological Medicine*, *29*(3), 527–538. https://doi.org/10.1017/s0033291799008338

Kessler, R. C., Adler, L., Barkley, R., Biederman, J., Conners, C. K., Demler, O., Faraone, S. V., Greenhill, L. L., Howes, M. J., Secnik, K., Spencer, T., Ustun, T. B., Walters, E. E., & Zaslavsky, A. M. (2006). The prevalence and correlates of adult ADHD in the United States: Results from the National Comorbidity Survey Replication. *American Journal of Psychiatry*, *163*(4), 716–723. https://doi.org/10.1176/ajp.2006.163.4.716

Kooij, J., Bijlenga, D., Salerno, L., Jaeschke, R., Bitter, I., Balázs, J., Thome, J., Dom, G., Kasper, S., Nunes Filipe, C., Stes, S., Mohr, P., Leppämäki, S., Casas, M., Bobes, J., Mccarthy, J. M., Richarte, V., Kjems Philipsen, A., Pehlivanidis, A., Niemela, A., {...} Asherson, P. (2019). Updated European Consensus Statement on diagnosis and treatment of adult ADHD. *European psychiatry : the journal of the Association of European Psychiatrists*, *56*, 14–34. https://doi.org/10.1016/j.eurpsy.2018.11.001

Lensing, M. B., Zeiner, P., Sandvik, L., & Opjordsmoen, S. (2013). Quality of life in adults aged 50+ with ADHD. *Journal of Attention Disorders*, *19*(5), 405–413. https://doi.org/10.1177/1087054713480035

Loo, S. K., Humphrey, L. A., Tapio, T., Moilanen, I. K., McGough, J. J., McCracken, J. T., Yang, M. H., Dang, J., Taanila, A., Ebeling H., Jarvelen, M. R. & Smalley, S. L. (2007). Executive Functioning Among Finnish Adolescents With Attention-Deficit/Hyperactivity Disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, *46*(12), 1594–1604. https://doi.org/10.1097/chi.0b013e3181575014

Luria, A. R. (1973). The Working Brain. Basic Books: New York

Macey, K. (2003). Conners' Adult ADHD Rating Scales (CAARS). By C.K. Conners, D. Erhardt, M.A. Sparrow. New York: Multihealth Systems, Inc., 1999. Archives of Clinical Neuropsychology, 18(4), 431–437. https://doi.org/10.1016/s0887 6177(03)00021-0

Matte, B., Rohde, L. A., & Grevet Eugenio Horacio. (2012). ADHD in adults: A concept in evolution. ADHD Attention Deficit and Hyperactivity Disorders, 4(2), 53–62. https://doi.org/10.1007/s12402-012-0077-3

Mattes, J. A. (1980). The role of frontal lobe dysfunction in childhood hyperkinesis. *Comprehensive Psychiatry*, *21*(5), 358–369. https://doi.org/10.1016/0010-440x(80)90017-6

Meere, J. J., Börger, N. A., & Wiersema, J. R. (2010). ADHD: State Regulation and Motivation. *Current Medical Literature. Psychiatry*, *21*(1), 14-20.

Mitchell, J. T., Howard, A. L., Belendiuk, K. A., Kennedy, T. M., Stehli, A., Swanson, J. M., Hechtman, L., Arnold, L. E., Hoza, B., Vitiello, B., Lu, B., Kollins, S. H., & Molina, B. S. (2018). Cigarette smoking progression among young adults diagnosed with ADHD in childhood: A 16-year longitudinal study of children with and without ADHD. *Nicotine & Tobacco Research*, *21*(5), 638–647. https://doi.org/10.1093/ntr/nty045

Modi, A. C., Vannest, J., Combs, A., Turnier, L., & Wade, S. L. (2018). Pattern of executive functioning in adolescents with epilepsy: A multimethod measurement approach. *Epilepsy & Behavior*, *80*, 5–10. https://doi.org/10.1016/j.yebeh.2017.12.021

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and Developmental Psychopathology. *Journal of Child Psychology and Psychiatry*, *37*(1), 51–87. https://doi.org/10.1111/j.1469-7610.1996.tb01380.x

Prasad, V., West, J., Kendrick, D., & Sayal, K. (2018). Attention-deficit/hyperactivity disorder: Variation by socioeconomic deprivation. *Archives of Disease in Childhood*, *104*(8), 802–805. https://doi.org/10.1136/archdischild-2017-314470

Riaz, A., Asad, M., Alonso, E., & Slabaugh, G. (2020). DeepFMRI: End-to-end deep learning for functional connectivity and classification of ADHD using fmri. *Journal of Neuroscience Methods*, *335*, 108506. https://doi.org/10.1016/j.jneumeth.2019.108506

Rovira, P., Demontis, D., Sánchez-Mora, C., Zayats, T., Klein, M., Mota, N.R., Weber, H., Garcia-Martínez, I., Pagerols, M., Vilar, L., Arribas, L., Richarte, V., Corrales, M., Fadeuilhe, C., Bosch, R., Español Martín, G., Álmos, P.Z., Doyle, A.E., Grevet, E.H. {...} & Ribasés, M. (2019). Shared genetic background between children and adults with attention deficit/hyperactivity disorder. *Neuropsychopharmacology, 45*, 1617 – 1626.

Salum, G. A., Sonuga-Barke, E., Sergeant, J., Vandekerckhove, J., Gadelha, A., Moriyama, T. S., Graeff-Martins, A. S., Manfro, G. G., Polanczyk, G., & Rohde, L. A. (2014). Mechanisms underpinning inattention and hyperactivity: Neurocognitive support for ADHD dimensionality. *Psychological Medicine*, *44*(15), 3189–3201. https://doi.org/10.1017/s0033291714000919

Seidman, L. J., Biederman, J., Faraone, S. V., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of attention deficit-hyperactivity disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical Psychology*, *65*(1), 150–160. https://doi.org/10.1037/0022-006x.65.1.150

Sibley, M. H., Graziano, P. A., Ortiz, M., Rodriguez, L., & Coxe, S. (2019). Academic impairment among high school students with ADHD: The role of motivation and goal-directed executive functions. *Journal of School Psychology*, *77*, 67–76. https://doi.org/10.1016/j.jsp.2019.10.005

Sinha, P., Sagar, R., & Mehta, M. (2008). Executive Function in Attention Deficit/Hyperactivity Disorder. *Journal of Indian Association for Child and Adolescent Mental Health, 4*, 44 - 49.

Slobodin, O., Cassuto, H., & Berger, I. (2015). Age-related changes in distractibility: Developmental trajectory of sustained attention in ADHD. *Journal of Attention Disorders, 22*(14), 1333–1343. https://doi.org/10.1177/1087054715575066

Spinella, M., (2005). Self-rated executive function: Development of the executive function index. *International Journal of Neuroscience, 115*(5), 649–667. https://doi.org/10.1080/00207450590524304

Tamm, L., Epstein, J. N., Lisdahl, K. M., Molina, B., Tapert, S., Hinshaw, S. P., Arnold, L. E., Velanova, K., Abikoff, H. & Swanson, J. M. (2013). Impact of ADHD and cannabis use on executive functioning in young adults. *Drug and Alcohol Dependence*, *133*(2), 607–614. https://doi.org/10.1016/j.drugalcdep.2013.08.001

Thorell, L. B., Holst, Y., & Sjöwall, D. (2019). Quality of life in older adults with ADHD: Links to ADHD symptom levels and executive functioning deficits. *Nordic Journal of Psychiatry*, *73*(7), 409–416. https://doi.org/10.1080/08039488.2019.1646804

Tsal, Y., Shalev, L., & Mevorach, C. (2005). The diversity of attention deficits in ADHD. *Journal of Learning Disabilities*, *38*(2), 142–157. https://doi.org/10.1177/00222194050380020401

Vogel, S. W. N., ten Have, M., Bijlenga, D., de Graaf, R., Beekman, A. T. F., & Kooij, J. J. S. (2018). Distribution of ADHD symptoms, and associated comorbidity, exposure to risk factors and disability: Results from a general population study. *Psychiatry Research*, *267*, 256–265. https://doi.org/10.1016/j.psychres.2018.06.017

Weyandt, L., DuPaul, G. J., Verdi, G., Rossi, J. S., Swentosky, A. J., Vilardo, B. S., O'Dell, S. M., & Carson, K. S. (2013). The performance of college students with and without ADHD: Neuropsychological, academic, and psychosocial functioning. *Journal of Psychopathology and Behavioral Assessment*, *35*(4), 421–435. https://doi.org/10.1007/s10862-013-9351-8

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V. & Pennington, B. F. (2005). Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Appendix A

Shapiro-Wilk test of Normality

Table A

Shapiro-Wilk test of Normality

	Shapiro-Wilk		
	Statistic	Df	Significance
CAARS Tscore ADHD Index	0.982	229	.006
CAARS_TScore Inattention	0.976	229	< .001
CAARS_TScore Hyperactivity	0.981	229	.003
CAARS_Tscore Impulsivity	0.961	229	< .001
CAARS_Tscore Selfconctrol	0.974	229	< .001
CAARS_Tscore DSM-IV_Total	0.960	229	< .001
CAARS_Tscore DSM-IV_Inattention	0.970	229	< .001
CAARS_TscoreDSM_Hyperactivity/Impulsivity	0.956	229	< .001
EFI Total	0.980	229	.003
EFI Motivational Drive	0.981	229	.004
EFI Organization_	0.983	229	.008
EFI Strategic Planning	0.987	229	.041
EFI Impulse Control	0.965	229	< .001
EFI Empathy	0.923	229	< .001

Appendix B

Correlations EFI subscales and CAARS ADHD indexes

Table B

Descriptive Statistics

	N	Mean	Std. Deviation
CAARS Tscore ADHD Index	229	53,29	10,78
CAARS_Tscore DSM-IV Total	229	56,85	13,26
EFI Total	229	95,53	10,66
EFI Motivational Drive	229	14,44	2,729
EFI Organization	229	14,86	3,769
EFI Strategic Planning	229	23,36	4,369
EFI Impulse Control	229	16,74	3,361
EFI Empathy	229	26,13	3,151

Appendix C

Correlations EFI subscales and CAARS ADHD indexes

Table C

Correlations EFI subscales and CAARS ADHD indexes

	CAARS ADHD Index			CAARS DSM-IV ADHD Total		
EFI subscale	n	Spearman's rho	p-value	n	Spearman's rho	p-value
Motivational Drive	229	-.068	.307	229	.047	.482
Organization	229	-.505	< .001	229	-.536	< .001
Strategic Planning	229	-.214	.001	229	-.265	< .001
Impulse Control	229	-.296	< .001	229	-.405	< .001
Empathy	229	-.038	.563	229	-.084	.207

Note: Correlation is significant at the .005 level (Two-tailed)

Appendix D

Table D1

Regression Coefficients Executive Functions on CAARS ADHD Index

Model		Unstandardized	Standard Error	Standardized	t	p	Collinearity Statistics: Tolerance	Collinearity Statistics: VIF
1	(Intercept)	86.144	6.245		13.795	< .001		
	MD_Total	-0.240	0.230	-0.061	-1.043	0.298	0.946	1.057
	ORG_total	-1.241	0.182	-0.434	-6.813	< .001	0.792	1.262
	SP_totaal	-0.013	0.167	-0.005	-0.080	0.936	0.704	1.421
	IC_totaal	-0.597	0.209	-0.186	-2.864	0.005	0.760	1.315
	EM_totaal	-0.024	0.218	-0.007	-0.112	0.911	0.792	1.263
2	(Intercept)	86.110	6.217		13.851	< .001		
	MD_Total	-0.241	0.230	-0.061	-1.048	0.296	0.947	1.056
	ORG_total	-1.245	0.173	-0.435	-7.212	< .001	0.878	1.139
	IC_totaal	-0.601	0.203	-0.187	-2.952	0.003	0.795	1.258
	EM_totaal	-0.030	0.206	-0.009	-0.145	0.885	0.880	1.136
3	(Intercept)	85.549	4.851		17.634	< .001		
	MD_Total	-0.248	0.224	-0.063	-1.105	0.271	0.990	1.010
	ORG_total	-1.243	0.172	-0.435	-7.241	< .001	0.884	1.132
	IC_totaal	-0.610	0.193	-0.190	-3.153	0.002	0.877	1.141
4	(Intercept)	81.747	3.420		23.902	< .001		
	ORG_total	-1.252	0.172	-0.438	-7.296	< .001	0.886	1.129
	IC_totaal	-0.588	0.192	-0.183	-3.056	0.003	0.886	1.129

Table D2

Model Summary regression Executive Functions on CAARS ADHD Index

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	,532[a]	,284	,267	9,227	,284	17,650	5	223	<,001
2	,532[b]	,284	,271	9,206	,000	,006	1	223	,936
3	,532[c]	,283	,274	9,186	,000	,021	1	224	,885
4	,529[d]	,280	,273	9,191	-,004	1,220	1	225	,271

a. Predictors: (Constant), EM_Total, ORG_Total, MD_Total, IC_Total, SP_Totaal
b. Predictors: (Constant), EM_Total, ORG_Total, MD_Total, IC_Total
c. Predictors: (Constant), ORG_Total, MD_Total, IC_Total
d. Predictors: (Constant), ORG_Total, IC_Total

Appendix E

Table E1

Regression Coefficients Executive Functions on DSM-IV ADHD Total Symptoms

Model		Unstandardized	Standard Error	Standardized	t	p	Collinearity Statistics Tolerance	VIF
1	(Intercept)	99.655	7.242		13.761	< .001		
	MD_Total	0.370	0.267	0.076	1.386	0.167	0.946	1.057
	ORG_total	-1.540	0.211	-0.438	-7.293	< .001	0.792	1.262
	SP_totaal	-0.121	0.193	-0.040	-0.625	0.533	0.704	1.421
	IC_totaal	-0.946	0.242	-0.240	-3.912	< .001	0.760	1.315
	EM_totaal	-0.252	0.253	-0.060	-0.998	0.320	0.792	1.263
2	(Intercept)	99.355	7.216		13.768	< .001		
	MD_Total	0.365	0.266	0.075	1.369	0.172	0.947	1.056
	ORG_total	-1.582	0.200	-0.450	-7.891	< .001	0.878	1.139
	IC_totaal	-0.977	0.236	-0.248	-4.138	< .001	0.795	1.258
	EM_totaal	-0.302	0.239	-0.072	-1.262	0.208	0.880	1.136
3	(Intercept)	93.678	5.651		16.578	< .001		
	MD_Total	0.295	0.261	0.061	1.131	0.259	0.990	1.010
	ORG_total	-1.561	0.200	-0.444	-7.803	< .001	0.884	1.132
	IC_totaal	-1.068	0.225	-0.271	-4.744	< .001	0.877	1.141
4	(Intercept)	98.214	3.984		24.652	< .001		
	ORG_total	-1.550	0.200	-0.441	-7.754	< .001	0.886	1.129
	IC_totaal	-1.094	0.224	-0.277	-4.880	< .001	0.886	1.129

Table E2

Model Summary regression Executive Functions on DSM-IV ADHD Total Symptoms

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	,603[a]	,363	,349	10,701	,363	25,421	5	223	<,001
2	,602[b]	,362	,351	10,686	-,001	,390	1	223	,533
3	,598[c]	,357	,349	10,700	-,005	1,593	1	224	,208
4	,595[d]	,354	,348	10,706	-,004	1,280	1	225	,259

a. Predictors: (Constant), EM_Total, ORG_Total, MD_Total, IC_Total, SP_Totaal

b. Predictors: (Constant), EM_Total, ORG_Total, MD_Total, IC_Total

c. Predictors: (Constant), ORG_Total, MD_Total, IC_Total

d. Predictors: (Constant), ORG_Total, IC_Total

Appendix F

Residual plots of regression models

Figure F1

Residuals versus predicted values final regression model EFI subscales CAARS ADHD Index

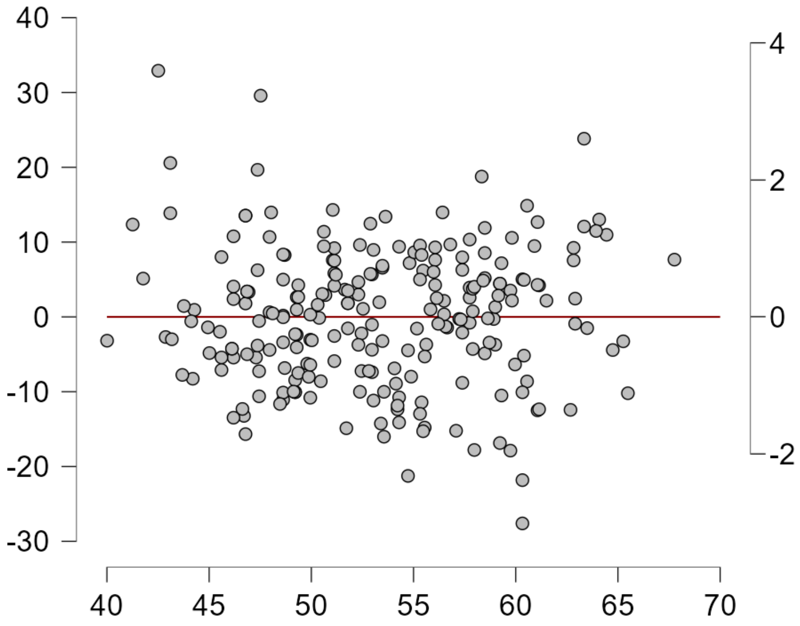


Figure F2

Residuals versus predicted values final regression model EFI subscales DSM-IV ADHD Total Symptoms